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FINAL REPORT ON THE STUDY OF THE RELATION OF FIRE INJURY TO BARK BEETLE ATTACK IN PONDEROSA PINE
(Tubb's Hill Burn)

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INTRODUCTION

Forest fires, especially those occurring in stands of western white pine, Pinus monticola D. Don, and ponderosa pine, Pinus ponderosa Lawson, have been known to cause a temporary increase of bark beetle damage. The type known as "light" or ground fire greatly increases the number of trees susceptible to insect attack. Some of these trees that are only slightly injured by the fire and would possibly recover are selected and killed by the attacks of various species of bark beetles and wood borers. Numerous questions in regard to the attractiveness of certain classes of fire-injured trees, their ultimate recovery if not attacked by bark beetles, and the rise and decline of insect infestations on burned areas still remain unanswered and it is only through intensive studies of the relation of fire injury to bark beetle attack can these problems be solved.**

An exceptional opportunity to study the relation of fire injury to bark beetle attack in ponderosa pine was made possible by the occurrence of a ground fire in 1928 on the south slope of Tubb's Hill at Coeur d'Alene, Idaho. This burn was particularly suited inasmuch as it was free from any salvaging operations following the fire.

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* Preliminary Report, Tubb's Hill Burn - July 18, 1929 - H. J. Rust
1929 Progress Report Tubb's Hill Burn - Jan. 24, 1930 - " " "
1930 Progress Report Tubb's Hill Burn - Feb. 5, 1931 - " " "

** J. M. Miller, J. E. Patterson, Preliminary Studies of the Relation of Fire Injury to Bark Beetle Attack in Western Yellow Pine. J. A. Research, Vol. 34, #7.

Summary

1. Conditions at time of fire - The Tubb's Hill burn is representative of many fires that have occurred throughout the ponderosa pine (*Pinus ponderosa*) stands in northern Idaho, particularly on the slopes of the hills bordering Coeur d'Alene Lake. The south slope of Tubb's Hill, where the fire under consideration occurred, had been free from any logging or woodcutting operations, but had been burned over one or more times in the past; attested to by old fire scars at the base on the uphill side of many of the larger ponderosa pines. Portions of the slope were very brushy preceding the 1928 fire and most of the brush as well as a large per cent of the small ponderosa pine reproduction was destroyed in the 1928 burn.

a. Date of Tubb's Hill burn, September 22, 1928.

b. Area burned over, 30 acres:
   1. By light ground fire representing 54.2 per cent of the stand - 14 acres.
   2. By medium fire damage representing 28.0 per cent of the stand - 7 acres.
   3. By severe crown fire representing 17.8 per cent of the stand - 9 acres.
      Total - 30 acres.

c. Cover type:
   Typical of the ponderosa pine type for eastern Washington and northern Idaho, ponderosa pine representing 98.4 per cent of the stand, Douglas fir 1.6 per cent. Crown development arranged according to "Dunning's Tree Classification" placed most of the trees in Classes III, IV, and VI.

d. Stand:
   A total of 1053 trees were included within the boundary of the burn with an estimated volume of 89,560 B. F. Average per acre - 2,985.3 B. F.

2. Extent of damage from fire - The varying intensity of the fire due to the irregular surface of the area, steepness of the slope, inflammability of the brush, needle covered duff and large witch's brooms on the lower crowns of many of the larger pines resulted in varied degrees of fire injury to the trees.

The effects of the fire were most noticeable in the scorching of the crowns. The base of the trees also showed the effects of scorching, but the extent of the damage to the root collar could not be accurately determined from the outward scorched appearance of the bark. The loss from trees burned through at the base by the fire was small; only five such trees being recorded.

A 100 per cent survey of the burned area was made shortly after the fire occurred. As a basis for future study of insect losses, all of the trees on the burn six inches d. b. h. and over were marked with a small blaze and a numbered metal tag. A separate record was made for each marked tree showing crown and bole development based on "Dunning's Tree Classification", the degree of fire injury to the crown, outward or visible injury to the root collar, evidence of insect attack, etc.

The volume of timber on the burn was grouped according to degree of fire injury to the crown in the following classes as originated and used by the Berkeley, California station as follows:

	Per cent of total stand by No. of trees	Per cent of total stand by volume
Class I. - No visible fire injury. No trees of this class on the burn.	--	--
Class II. - Less than 25 per cent of lower crown defoliated.	37.8	59.2
Class III.- From 25 to 50 per cent of crown defoliated.	16.4	17.0
Class IV. - From 50 to 75 per cent of crown defoliated.	10.5	7.0
Class V. - 75 to 100 per cent defoliated, terminals not killed, cambium green.	17.5	10.8
Class VI. - 100 per cent defoliated, terminal buds killed, cambium severely scorched; fire killed.	17.8	6.0
Total --	100.0	100.0

GENERAL DEVELOPMENTS ON BURN BY YEARS

1928 - In addition to the trees in Class VI killed by the fire at the time of the burn, 1.6 per cent of the stand representing 9 per cent of the total volume of ponderosa pine was successfully attacked by the mountain-pine beetle, (Dendroctonus monticolae Hopk.) shortly after the fire occurred. This was a very unusual occurrence both from the fact that no previous losses due to the attacks of this bark beetle had been recorded from the area, and also because of the lateness of the season when the attacks occurred. The source of this infestation was from a large boom of white-pine logs lying in storage in the water at the base of the hill at the time of the fire. These logs had been but recently transported by rail from a known area of mountain-pine beetle infestation 26 miles distant.

1929 - The survey for the year following the fire showed that the less severely fire-scorched trees in Classes II and III fire injury to crown that had escaped attacks by bark beetles, had developed new needle growth. Those surviving in Classes IV and V had shed many of the fire-scorched needles and most of the new growth was confined to the top portion of the crown. The mountain-pine beetle infestation which had developed in 1928 had dwindled down to one small ponderosa pine attacked in 1929. A decided increase in the number of trees attacked by the western-pine beetle (Dendroctonus brevicomis) and the Oregon engraver beetle (Ips oregoni Eich.) were recorded. These losses occurred mostly in the severely scorched trees of Classes IV and V crown and root collar injury.

1930 - The growing season for 1930 was unusually long and dry and it was expected that this drought condition would have a decided effect on the most severely fire-scorched trees in Classes IV and V which had survived the fire and insect attack. The annual survey for this season made during October showed a noticeable loss in foliage and increment, but no direct loss in number of trees. A slight increase in the number of trees attacked by the mountain-pine beetle was recorded. This increase resulted in no greater loss of volume than was recorded for 1929 as the attacked trees were small and severely fire injured. The western-pine beetle showed a decrease of 50 per cent in number of trees from the previous year. A large per cent of the trees selected for attack were in Class V fire injury to the crown and with varying degrees of fire injury to the root collar. The Ips oregoni infestation had declined 61 per cent from the number of trees attacked in 1929, the selection still falling in classes of severe damage to crown and root collar.

1931 - The 1931 season was also long and dry and the result of continued drought was more noticeable this season in the loss of foliage and increment of the fire-injured trees, particularly those in Classes IV and V. The remaining smaller suppressed trees died during the summer, some of them showing no indications whatever of insect attack. The survey for this year showed the total absence of the mountain-pine beetle on the burn. The western-pine beetle attacks had dwindled down to near the normal number of trees annually killed by this bark beetle on the slope prior to the 1928 fire. The Ips oregoni infestation had left the smaller fire damaged trees and had concentrated in the tops of three large ponderosa pines on the burn that were in Classes II and III fire injury to crown. A few of the larger severely fire-scorched trees that were attacked by bark beetles in 1928 and 1929 began to fall from the effects of fire, decay and wood borer work. A number of the smaller trees killed by fire and insects were also falling, many of which had been severely burned at the root collar.

1932 - The fifth and final survey of the burn showed the total absence of all Dendroctonus and Ips beetles. The only insects actively present were wood borers in the smaller decadent and most severely fire-injured trees. The western-pine beetles emerging from the trees attacked on the burn in 1931 shifted their activities to a group of trees 150 yards northwest of the boundary of the burn for the spring and summer attacks and the selection for the over-wintering generation was on the south slope, 160 yards from the boundary of the burn. Twenty-five per cent of the trees killed by fire and insects were now down, those from 6 to 10 inches in diameter beginning to show decided effects of decay. Precipitation for the 1932 season was way above normal and the effects of the heavy rainfall were noticeable in the development of plant growth on the burned area. A large per cent of the shrubs that had been burned to the ground at the time of the fire had developed new growth and with the recovery of the usual plant life, the area began to assume normal conditions.

The approximate per cent of loss and survival by volume as recorded by the five annual surveys, 1928 to 1932 inclusive, is as follows:

	Per cent of total stand by volume	Per cent of total stand by trees
Killed by fire........................	6.0	18.0
Killed by fire and insects............	14.0	12.8
Killed by insects.....................	3.0	1.2
Total.....	23.0	32.0
Surviving October, 1932...............	77.0	68.0
	100.0	100.0

The per cent of volume killed in each class surviving the fire was estimated as follows:

Fire injury to crown	Per cent of class dying subsequently to fire (volume)
Class I. - No injury. No trees..................	--
Class II. - Less than 25 per cent defoliation......	14.5
Class III.- 25 per cent to 50 per cent defoliation.	14.1
Class IV. - 50 per cent to 75 per cent defoliation.	18.7
Class V. - 75 per cent to 100 per cent "	44.6

Increased injury to the root collar caused from the burning of the extra accumulation of duff on the uphill side of many of the larger pines that escaped severe crown injury was apparent. This severe root collar injury was found to be a deciding factor in the selection of many of the fire-injured trees by bark beetles. A graded scale of per cent of injury to the root collar was devised by the Coeur d'Alene station and used in connection with this burn.

The correct degree of fire injury to the root collar could only be determined by removing a strip of bark from around the entire bole at the surface of the ground and measuring the amount of outer wood and cambium damaged by the fire. This method was only possible after the trees had been attacked by insects; otherwise, the girdling would have caused serious injury to trees that otherwise might possibly recover from the effects of the fire.

Per cent of trees and volume attacked by bark beetles grouped according to degrees of fire injury to root collar:

	Per cent of total stand by trees	Per cent of total stand by volume
Class I. - No visible fire injury..	-	-
Class II. - Up to 25 per cent of root collar damaged.....	3.5	2.2
Class III.- 25 to 50 per cent of root collar damaged.....	3.0	3.4
Class IV. - 50 to 75 per cent of root collar damaged.....	2.5	3.5
Class V. - 75 to 100 per cent of root collar damaged.....	4.0	5.6
Class VI. - 100 per cent of root collar damaged..........	3.0	4.3
Total.....	16.0	19.0

Infestations by Different Insects Developing After Fire

Owing to the lateness of the season when the fire occurred, flights of the western-pine beetle, Ips species, and the various species of wood borers usually found in ponderosa pine stands had practically ceased for the season. However, a large number of mountain-pine beetles were attracted to the burn shortly after the fire occurred. The attacks were concentrated on 17 of the larger severely fire-scorched ponderosa pines and scattered on 59 others. If the beetles which had unsuccessfully attacked the 59 large pines concentrated on a smaller number of trees, possibly ten, a much heavier loss to the fire-injured trees would have occurred as none of these lightly attacked trees were killed. As a result, practically 37 per cent of the total number of attacking beetles were destroyed by the resistance of the trees selected. When examined in 1929, 89 per cent of the 1928 successfully attacked trees showed that a normal emergence had taken place, but the number of attacked trees for 1929 had decreased 94 per cent and the total volume 98 per cent. A slight increase in number of trees attacked for 1930 was recorded, but with no increase over 1929 in volume b. f. destroyed. In 1931, the area was abandoned by the mountain-pine beetle. Of the 21 trees successfully attacked by this bark beetle for the three years, distributed among the classes of fire injury, 81 per cent of them came under severe root collar injury in Classes IV, V and VI, with additional injury to the crowns, and the insect attacks in these severely fire-injured trees were considered as secondary in the death of the trees.

Four per cent of the fire-injured trees was attacked at the base by the red turpentine beetle (Dendroctonus valens Lec.) the year following the fire. In 24 per cent of these trees other bark beetle attacks followed. No apparent damage resulted, however, to the remaining trees from the attacks of this bark beetle.

Various species of wood borers including both Cerambycidae and Buprestidae began to work on the most severely fire scorched and bark beetle attacked trees in 1929. During 1930, 23 trees were heavily attacked by these insects resulting in a slight loss in volume. In 1931, eight small trees, and during 1932, 5 of the smaller fire-injured trees were attacked by the same species, resulting in negligible loss in volume.

The light _Ips oregoni_ infestation present on the area preceding the fire increased 1154 per cent in number of trees attacked the year following the fire. The second year (1930) showed an increase of but 155 per cent over the 1928 attacks or a decrease of 999 per cent from the 1929 attacks. In 1931, the attacks were concentrated in the top portion of three large ponderosa pines and in 1932 no _Ips oregoni_ attacks were recorded for the burn. Fifty-eight per cent of the trees selected for attack in 1929 were in Class VI fire injury to crown, and were considered as killed by the fire. The remaining 42 per cent attacked were sufficiently fire injured both to crown and root collar to make their recovery from the fire very doubtful.

The western-pine beetle was the most abundant bark beetle associated with the killing of ponderosa pine which survived the serious effects of the fire. An increase of 567 per cent in number of trees attacked was recorded for the year following the fire. The second year showed an increase of but 233 per cent over the normal 1928 attacks or a decrease of 50 per cent from the previous year. The third year (1931) the infestation had returned to approximately the number of trees killed annually on the slope prior to the fire, but with an increased volume due to the selection of larger trees. The fourth year (1932) the western-pine beetle left the burned area entirely and concentrated in ponderosa pine a short distance from the boundaries of the burn. The increased activities of the western-pine beetle on the burn during 1929 and 1930 apparently had no effect in attracting beetles to the surrounding stands as no infested trees were found, indicating a direct influence from the fire in attracting all nearby beetles to the severely fire-injured trees, this added attraction lasting for two seasons following the fire.

A considerable amount of bark containing overwintering broods of the western-pine beetle was taken from fire scorched trees on the burn in the spring of 1930, and placed in rearing cans for securing reliable data on emergence. An average per square foot emergence of 274 beetles was secured from this material, showing an average increase of 1091 per cent over the number of beetles attacking, assuming the number of parent adult beetles per attack equalled two. The emergence per square foot of bark surface for this region secured from a large amount of infested bark surface was found to have a range from 109 to 512 with a general average of 307 beetles. The average secured from the infested bark from the burn compared very favorably with the average secured from isolated trees over a number of years. The removal of the infested bark from the burn no doubt had an influence in reducing the amount of infestation on the area for 1930 possibly by 2 or 3 trees.

Growth Conditions as an Attraction to Bark Beetle Attack

Ring growth counts were made from cores taken from all the trees on the burn that had been successfully attacked by bark beetles. An equal number of cores for comparison were taken from a selection of ponderosa pine in Class II fire injury to crown and of diameter classes corresponding to those attacked. This comparison showed a decided tendency by both the mountain and western-pine beetles for the slower growing trees. This was particularly the case with the latter species. The average number of rings for the last one-half inch in the selection of cores from unattacked trees was 13, for the trees selected by the mountain-pine beetle 16, and for the western-pine beetle 16.5.

An arrangement showing the growth rate of unattacked trees and selection by *D. monticolae* and *D. brevicomis* follows:

	Cumulative per cent and number of trees showing more than -				
	25 rings last ½ inch	20 rings last ½ inch	15 rings last ½ inch	10 rings last ½ inch	5 rings last ½ inch
Unattacked					
Per cent	1.7	8.4	31.8	85.2	100
No. of trees	1	5	19	51	60
Attacked by *D. monticolae*					
Per cent	4.8	19.1	62.0	95.3	100
No. of trees	1	4	13	20	21
Attacked by *D. brevicomis*					
Per cent	23.0	28.1	64.0	81.9	100
No. of trees	9	11	25	32	39

The selection of slow growing trees showing more than 15 and less than 20 rings per last one-half inch was quite constant with both species of Dendroctonus but beginning with 20 and more rings *Dendroctonus brevicomis* took a decided lead over *D. monticolae* which continued through the slower growing trees. This same relation of attack to slow growth was found with the cores examined taken from the 1932 *D. brevicomis* attacked and unattacked trees outside the boundaries of the burn.

TREE DIAMETERS AND DEGREES OF FIRE INJURY SELECTED FOR ATTACK BY THE MOUNTAIN AND WESTERN-PINE BEETLES

The selection of trees of certain diameters seems to have been a definite factor for both of the species of Dendroctonus bark beetles attracted to the burn. The average d. b. h. for the trees both successful and pitched-out attacks by the mountain-pine beetle during 1928 was found to be 20 inches. The few decadent trees attacked by this beetle during 1929 and 1930 only reached an average of 11 inches and represented attacks by a very few beetles that had remained or were attracted to the area.

Eighty-one per cent of the ponderosa pine successfully attacked by the mountain-pine beetle was sufficiently fire injured either to the crown or root collar or both as to place the bark beetle attacks as secondary in the death of the trees. Of the 81 per cent severely fire injured, 28.5 per cent was in Class IV root collar injury, 24 per cent in Class V, and 28.5 in Class VI.

The diameter of trees selected for attack by the western-pine beetle ranged from 10 to 24 inches with an average of 15 inches d. b. h. Severely fire damaged trees seemed to be an added attraction in the choice for attack. There were 21 trees on the burn 15 inches or over in d. b. h. that were placed in Class V fire injury to the crown. The mountain-pine beetle selected three of these trees and the western-pine beetle attacked the remaining 18. The total selection of trees for attack by the western-pine beetle was represented by 59 per cent in the severe crown injury classes and by 64 per cent in the most severe root collar injury. Only 1.2 per cent of the fire-injured trees attacked by the Dendroctonus bark beetles was considered as killed from insect attack alone.

SALVAGING FIRE-INJURED TREES

The question of salvaging fire scorched trees on burned areas similar to the one under discussion is an important factor to be considered from a silvicultural or lumbering viewpoint.

To determine what trees would be the most susceptible to insect attack following the fire, all those of merchantable size on the burn were arranged according to "Dunning's Tree Classification" regardless of their injury by fire. This arrangement showing the per cent of number of trees, volume b. f., and insect losses in each class is shown in the following table:

PONDEROSA PINE ON TUBB'S HILL BURN ARRANGED ACCORDING TO
"DUNNING'S TREE CLASSIFICATION" WITH PER CENT OF NUMBER OF TREES,
VOLUME, BOARD FEET AND INSECT LOSSES IN EACH CLASS FOR FIVE-YEAR PERIOD

Class	Per cent of trees	Per cent of volume B.F.	Selection by D.monticolae		Selection by D.brevicomis		Total loss: per cent of trees	Total loss per cent of vol.
			Per cent of trees	Per cent of vol.	Per cent of trees	Per cent of vol.		
I	1.0	2.4	-	-	-	-	-	-
II	11.7	10.0	14.3	6.9	2.6	2.5	16.9	9.4
III	12.4	26.1	19.1	13.9	7.6	6.1	26.7	20.0
IV	21.9	46.1	28.5	9.8	28.2	16.7	56.7	26.5
V	00.3	2.0	0.0	0.0	0.0	0.0	00.0	00.0
VI	51.0	12.6	38.1	1.4	59.0	8.7	97.1	10.1
VII	1.7	.8	0.0	0.0	2.6	0.0	0.0	0.0

The above tabulation shows the heaviest loss from insects to fall in Classes III, IV and VI. The selection in number of trees by D. monticolae and D. brevicomis was very nearly equal in Class IV. This class represented the largest volume b. f. and the heaviest loss from a commercial viewpoint. Class III was next in importance in point of volume losses; and while Class VI shows the heaviest loss in numbers it did not represent much loss in volume. The element of severe fire injury greatly influenced the large selection of trees by insects in this class. From the information secured from this study in ponderosa pine, Classes III and IV would represent the trees to be salvaged following a fire similar to the Tubb's Hill burn.

BASIS FOR FINAL REPORT

A preliminary report on the Tubb's Hill burn study was submitted on July 18, 1929, which covered the data collected on the 1928 survey a short time after the fire occurred. The more important points covered in this report were:

1. Description of the area and character of the fire.
2. Extent and method of survey.
3. Classification of fire damage both to crown and root collar and number and volume of fire damaged trees in each class of injury.
4. Insect losses within the burned area.
5. Source of infestation by the mountain-pine beetle.
6. Insect losses in ponderosa pine on the area prior to the 1928 burn.
7. Map of the burn and surrounding areas.

Progress reports for the years 1929 and 1930 were submitted January 24, 1930, and February 5, 1931, respectively. These reports covered additional data secured from the annual 100 per cent surveys made during October of each year. The data presented consisted mainly of additional losses to the fire-injured trees by the attack of various species of bark beetles and wood borers, and also the tabulation of the fire-injured trees arranged according to "Dunning's Tree Classification".

The annual survey for 1931 showed the absence of the mountain-pine beetle on the area and the return to near normal conditions by the western-pine beetle and no progress report was presented for that year.

The 1932 survey showed the total absence of all bark beetles on the area. A slight loss in number of trees was recorded for various species of wood borers. This loss may continue for several years to come in the decadent, spike-topped and broken-topped trees.

The following tabulation shows a summary of all the bark beetle attacked trees arranged according to fire injury to crown and root collar and per cent of volume losses in each class:

TABLE 1.

DENDROCTONUS MONTICOLAE

Fire Injury Class	Year of Attack					
Crown Injury	1928	1929	1930	1931	1932	Total
Class I.						
No. of trees	-	-	-	-	-	-
Class II.						
No. of trees	6	0	0	0	0	6
Class III.						
No. of trees	2	1	1	0	0	4
Class IV.						
No. of trees	3	0	0	0	0	3)
Class V.						)
No. of trees	1	0	2	0	0	3) 52%
Class VI.						)
No. of trees	5	0	0	0	0	5)
Total	17	1	3	0	0	21

Fire Injury Class	Year of Attack					
Root Collar Injury	1928	1929	1930	1931	1932	Total
Class I.						
No. of trees	-	-	-	-	-	-
Class II.						
No. of trees	1	0	1	0	0	2
Class III.						
No. of trees	2	0	0	0	0	2
Class IV.						
No. of trees	5	0	1	0	0	6)
Class V.						)
No. of trees	3	1	1	0	0	5) 81%
Class VI.						)
No. of trees	6	0	0	0	0	6)
Total	17	1	3	0	0	21

A comparison of the two types of fire injury shows only 52 per cent of the selection falling in severe injury to crown while 81 per cent occur in severe injury to the root collar. The injury to the base of the tree would seem to be a much more dominant factor than injury to the crown in considering the selection of fire-injured trees by the mountain-pine beetle on the Tubb's Hill burn.

Ponderosa pine on Tubb's Hill burn successfully attacked by the western-pine beetle arranged according to fire injury to crown and root collar:

TABLE II

DENDROCTONUS BREVICOMIS

Fire Injury Class	Year of Attack					
Crown Injury	1928	1929	1930	1931	1932	Total
Class I.						
No. of trees	-	-	-	-	-	-
Class II.						
No. of trees	-	5	3	3	0	11
Class III.						
No. of trees	-	3	2	0	0	5
Class IV.						
No. of trees	-	2	0	0	0	2)
Class V.						)
No. of trees	-	6	8	3	0	17)
Class VI.						)
No. of trees	-	4	0	0	0	4) 59%
Total	-	20	13	6	0	39

Fire Injury Class	Year of Attack					
Root Collar Injury	1928	1929	1930	1931	1932	Total
Class I.						
No. of trees	-	-	-	-	-	-
Class II.						
No. of trees	-	2	5	0	0	7
Class III.						
No. of trees	-	3	2	2	0	7
Class IV.						
No. of trees	-	7	3	0	0	10)
Class V.						)
No. of trees	-	7	2	4	0	13) 64%
Class VI.						)
No. of trees	-	1	1	0	0	2)
Total	-	20	13	6	0	39

A comparison of the two types of fire injury shows 59 per cent of the selection in classes of severe injury to the crown and 64 per cent in classes of extreme injury to the root collar. The predominence of selection by this bark beetle as with the mountain-pine beetle fell in the classes of the most severe damage to the root collar. This can be partly explained from the fact that the diameter selection by the mountain-pine beetle averaged 20 inches, and that of the western-pine beetle was from 15 to 24 inches. The diameter selection by these two bark beetles represented some of the larger trees on the area which were growing in a more open stand and free from reproduction. These larger trees were subject to a heavy scorching at the base partly due to the accumulation of duff on the uphill side and the condition of the root system, which owing to a rather shallow covering of soil was partly exposed in a number of the trees and resulted in severe damage to the root collar. Fire injury to the crown on many of these larger trees was the result of large witch brooms on the lower crown catching on fire from the ground blaze.

SUMMARY OF FIRE INJURED AND FIRE AND INSECT KILLED TREES ON THE BURN

Class	Total volume on burn after fire		Total Killed Fire & Insects		Total per cent of class killed	
	Trees	Volume	Trees	Volume	Trees	Volume
I. No injury to tree	0	0	0	0	0	0
II. Less than 25% defoliated by fire.	397	53060	25	7730	6.3	14.5
III. 25 to 50% of crown defoliated by fire.	173	15150	17	2150	9.8	14.1
IV. 50 to 75% of crown defoliated by fire.	111	6390	16	1190	1.5	18.7
V. 75 to 100% of crown defoliated. Terminal buds and cambium green.	185	9660	88	4310	47.0	44.6
VI. 100% of crown defoliated, cambium scorched, buds killed.	187	5300	Fire Killed 187	5300	100.0	100.0
Total	1053	89560	333	20680		23.0

A summary of the total losses for five years on the burn, from the effects of the fire and insect attacks shows a loss of 333 trees or 32 per cent of the stand representing a loss of 23 per cent of the total volume. Of the 32 per cent of trees killed, 18 per cent was destroyed from the effects of the fire, 12.8 per cent from a combination of fire and insect attack and 1.2 per cent by insect attack alone.

FIRE-INJURED TREES ATTRACTIVE TO BARK BEETLES

When bark beetles leave areas of green standing timber and concentrate on a freshly burned area there is apparently an attraction exerted by the fire-injured trees. Each species of bark beetle represented may respond to a different attraction and the extent of the damage caused by the attacking beetles may vary considerably governed somewhat by the time of the season when the fire occurs. Certain facts regarding this attractive value of fire scorched trees were secured from the study of the Tubb's Hill burn. Approximately 6 to 10 days after the fire occurred a large number of mountain-pine beetles were attracted to the burn. It was assumed that these beetles had emerged from infested white pine logs lying in the water at the base of the hill, as the nearest known infestation was 26 miles distant and in white pine stands. A similar occurrence took place on the opposite side of the lake 1½ miles distant where a lesser number of white pine logs were stored. A fire in a nearby ponderosa pine stand occurring almost at the same time as the Tubb's Hill burn attracted a number of mountain-pine beetles to the severely scorched trees. These areas had been under observation since 1917 as check areas in the study of insect losses by the western-pine beetle in this region, and prior to 1928 no ponderosa pine had been found attacked by Dendroctonus monticolae Hopk. A large per cent of the ponderosa pine successfully attacked by the mountain-pine beetle on the Tubb's Hill burn was close to the shore line where the logs were stored. An examination made in 1929 of the 1928 attacked trees showed that in a large per cent of the trees, normal broods had developed with a corresponding emergence, however, the infestation had dwindled down to almost nothing. The 1928 stored logs were moved and replaced by new booms after emergence of the mountain-pine beetles on the burn had taken place in 1929. An examination was made of these logs on September 19, 1929, and an emergence of the mountain-pine beetle was found in progress. The emerging beetles were attacking the top portion of nearby white pine logs above the water line, the ponderosa pines on the burned area apparently having lost their attractive value to this bark beetle. The mountain-pine beetle infestation on the burn in 1930 was still declining, and disappeared altogether from the area in 1932. A number of the 1928 unsuccessfully attacked mountain-pine beetle trees were still available on the burn and it would seem that there had been an added attraction in the freshly scorched trees that disappeared before the emergence of the overwintering broods in 1929.

With the western-pine beetle a normal infestation had been in progress in the ponderosa pine stands on Tubb's Hill for a number of years prior to the 1928 burn. The annual losses from this beetle on the area had been recorded since 1917 by the Coeur d'Alene Forest Insect Field Station. At the time of the burn there were three _Dendroctonus brevicomis_ trees on the area. Nearly all the bark was stripped from these trees by woodpeckers during the winter of 1928 and 1929, but no doubt a small per cent of the larvae developed, emerged and helped supply the large increase found on the burn for 1929. The fire occurred too late in 1928 to be attractive to this bark beetle for that year, but an attraction continued throughout 1929, drawing beetles from a considerable distance. The second season after the fire, the western-pine beetle attacks began to decline rapidly, returning to normal in the third year and abandoning the burned area in the fourth year. The selection of trees for 1932 was of the same general crown classes ("Dunning's Tree Classification") and rate of growth as those found attacked on the burn during the previous years. Judging from this selection so near the boundary of the burn, it would seem that the remaining standing fire-injured trees had lost their attractiveness to this bark beetle.

Attacks by the Oregon engraver beetle, Ips oregoni, had also ceased for the year at the time of the Tubb's Hill fire, but the following season showed a very large increase of these beetles on the area. The second season the infestation began to decline and the third year the attacks were confined to the tops of several large ponderosa pines. The fourth year after the fire this bark beetle had entirely abandoned the area.

CONCLUSIONS

The final report of the Tubb's Hill fire concludes a five-year study of a burn in ponderosa pine on an area where there had been a known average loss of 3.3 trees each year killed by the western-pine beetle and a few small trees killed by Ips oregoni for 12 years prior to the 1928 fire.

The immediate loss by the fire was 18.0 per cent of the stand representing 6.0 per cent of the total volume. The subsequent losses by a combination of fire and insects in which the insect attack was considered as secondary in the death of the tree was 12.6 per cent of the total number of trees. The actual loss by insect attack on trees that would have recovered from slight fire injury represented but 1.2 per cent of the total number of trees on the area and 3.0 per cent of the total volume. This loss was comparable to the normal annual loss on the slope for the 12 years prior to the 1928 fire. The fire occurred too late in September to attract any western pine or Ips oregoni beetles for that year. The freshly scorched trees, however, did attract a large number of mountain-pine beetles emerging from white pine logs stored in booms in the lake. This attraction was unusual and resulted in a number of the larger severely fire-injured trees being attacked by this beetle. Normal broods developed the following season, but the infestation disappeared from the area in 1929, and while large numbers of infested white pine logs had been stored near the burn for the four succeeding years, no recurrence of the attraction to the remaining fire scorched trees was recorded. The first year following the fire large numbers of the western-pine beetle and Ips oregoni were attracted to the burn resulting in a heavy increase in number of trees attacked by these bark beetles. The second year this infestation began to decline and a return to near normal was reached the third year.

The selection of fire-injured trees for attack by bark beetles attracted to the area was recorded in classes of both severe injury to the crown and root collar, and the increased infestation on the area lasted only while this type of severely injured tree was available. As nearly all of the trees attacked were beyond recovery from the effects of the burn, no additional losses resulted from the attacks by the western-pine beetle and Ips oregoni either within the boundary of the burn or on surrounding areas. A comparison of the two classes of fire injury showed that a much greater per cent selected for attack by bark beetles fell in classes of severe injury to the root collar and this type of fire injury was found more important for consideration than injury to the crowns as it represented heavy losses in the larger merchantable trees growing in the more open stand.

The five-year study of the Tubb's Hill burn showed that for fires of this type recommendations for salvaging the fire-injured trees should be particularly confined to trees represented by Classes III and IV, "Dunning's Tree Classification". A brief description of these two classes follows:

"Class III, thrifty-mature or mature (150-300 yrs.), isolated or dominant, crown lengths 65 per cent or more; crown width, average or wider; seed bearing capacity, very good; form of top, rounded; Vigor, moderate; approximate diameter, 18" to 40"; cutting decision, usually leave for seed, value in increment and volume; risk, fair to good. Class IV, mature (150-300 yrs.) usually co-dominant; crown lengths up to 65 per cent; crown width, less than average; greatest insect risk; seed bearing capacity, fair to good; vigor, moderate to poor; form of top, rounded; cutting decision, usually cut subject to insect attack; risk, poor to fair. Except for the small poorly developed crown, smaller size and lower vigor, similar to Class III."

Of these two classes, No. IV was found to have been the most attractive for bark beetle selection both before the 1928 fire and for the four years following. This class as well as Class III represented the larger merchantable trees growing in the more open stand and was subject to severe root collar injury from the accumulation of duff at the base. The exact amount of damage to the root collar can only be secured by removing a strip of bark from around the bole at the base of the tree. A fair idea of the injury, however, can be secured by a visual examination when the damage results in Classes IV, V and VI injury to the root collar. As the classes arranged according to "Dunning's Tree Classification" are based on the development of the bole and crown, fire injury to the crown is more easily determined. If only slightly injured either to the crown and root collar, Classes III and IV still represent suitable material for insect losses as they offer the preferred diameters and slow rate of growth which were also found to be deciding factors in the selection of host material by the Dendroctonus bark beetles found on the area.

Respectfully submitted,

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PLATE 1.

View of part of the lower portion of the south slope of Tubb's Hill, Coeur d'Alene, Idaho, which was subject to a ground fire occurring on September 28, 1928. The fire started in the lower left-hand corner and swept to the top of the hill before being controlled. This view shows the characteristic slope type of ponderosa pine for this region and a number of the larger trees in Class III and IV which are usually subject to severe root collar injury owing to the accumulation of duff at the base; particularly on the uphill side. The heaviest losses from bark beetles occurred in these larger trees growing in the more open stand.

Plate 1

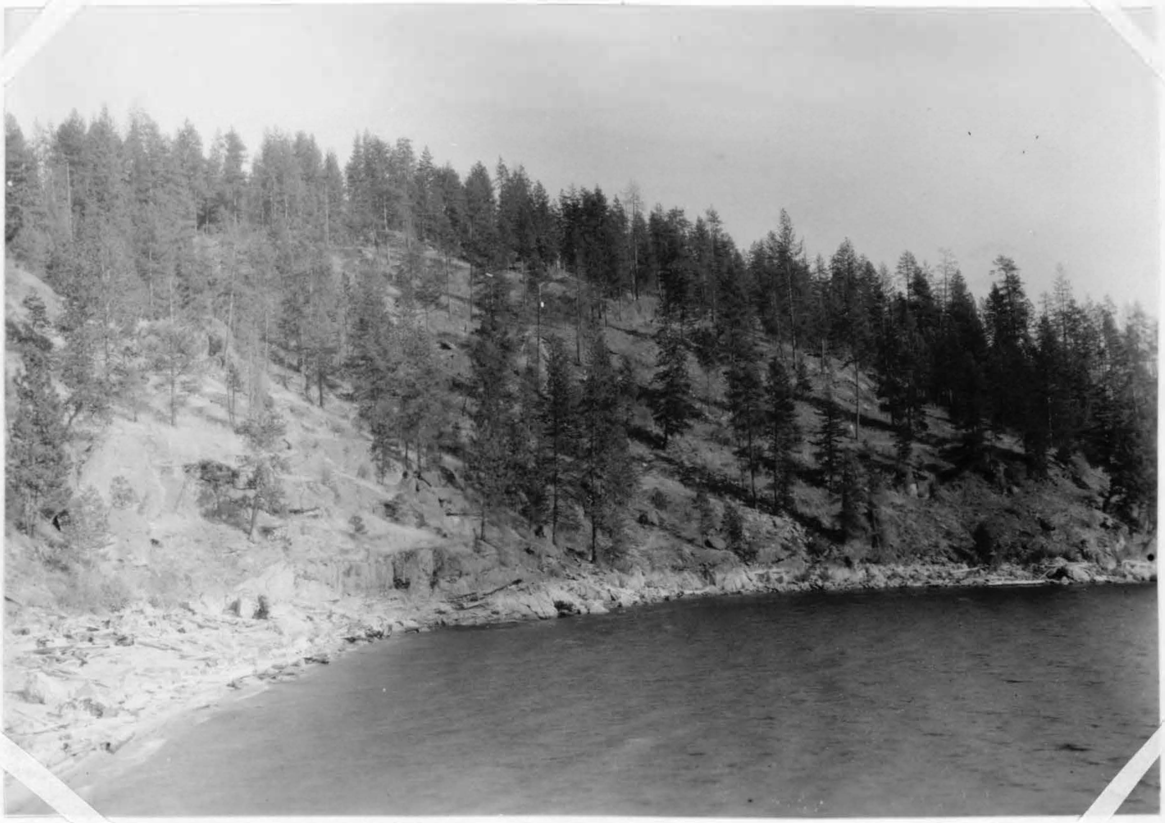

PLATE 2.

View showing white pine (*Pinus monticolae* D. Don) logs stored in booms on Coeur d'Alene Lake along the west shore of Tubb's Hill. The white pine area 26 miles distant from which these logs are cut and transported by rail is infested by *Dendroctonus monticolae*. It was from such infested stored logs that the mountain-pine beetles were attracted to the fire scorched ponderosa pine shortly after the fire occurring September 28, 1928. During the latter part of September, 1929, mountain-pine beetles emerging from the stored logs were found to be attacking the top portions of green white pine logs near by.

Plate 2